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APOLLO LOGISTICS SUPPORT SYSTEMS MOLAB STUDIES

TV SUBSYSTEM STUDIES FOR A LUNAR MOBILE LABORATORY

Prepared under Contract No. NAS8-5307 by

J.C. McBride

HAYES INTERNATIONAL CORPORATION
Missile and Space Support Division
Apollo Logistics Support Group

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TV SUBSYSTEM STUDIES FOR A
LUNAR MOBILE LABORATORY
By
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ABSTRACT

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Three classifications of camera tubes are considered for a slow scan, shuttered operation in a Lunar Mobile Laboratory. The material is based on previous documentation of tests made on similar types of operations, rather than on local testing. The choice of the SEC Vidicon is based on the further testing of the ability of this tube to withstand the space environment.

The earth control station for the remote driving of the MOLAB is described as to the display of the information necessary for successful operation. Three methods of display of stereo television are described with the advantages and disadvantages of each listed. A possible method for including predicted position information on the television display is also included.

The uses of television during the manned phase, i.e., the aids to the scientific mission, also are investigated. Suggestions for providing a limited spectral analysis capability to the television are suggested.

Feasibility of including a television monitor in the Command and/or the Lunar Excursion Module is considered as to the weight, volume, and

power penalties. The weight and volume trends are described as the screen size varies, and two examples of space qualified monitors are included.

Author

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ASTRIONICS LABORATORY

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PREFACE

This report was prepared by Hayes International Corporation, Apollo Logistics Support Group, Huntsville, Alabama, for the George C. Marshall Space Flight Center under the authorization of Task Order H-41, Contract NAS8-5307.

The NASA Technical Liaison Representative was Mr. E. C. Hamilton,R-ASTR-AE.

This work completed a 112 man-days effort beginning on October 15, 1964 and ending on March 31, 1965.

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1.1 INTRODUCTION

In the evaluation of camera tubes for a specific purpose, the conditions under which this tube must operate should first be specified. Since the camera is expected to operate during both the lunar day and night, some realistic values should be given for the available illumination under these conditions. These may be derived by the following expression:

$$\mathcal{B} = \frac{E \rho \phi}{\pi}$$

where

$\mathcal{B}$ = Surface brightness in candles/m^2

E = Source illumination in lumens/m^2 (lux)

ρ = Lunar albedo

ϕ = Lunar photometric function

The value of the photometric function ϕ is derived from the lighting and viewing angles with a good assumption for this purpose being 0.2. The lunar albedo varies from 0.176 to 0.05 and will be assumed here to be 0.07. The surface brightness then is:

	E	$\mathcal{B}$
Lunar day	15.7×10^4 lux	700 candles/m^2
Lunar night (earthshine)	7.58 lux	0.034 candles/m^2

This means that the camera is viewing a surface having a brightness variation of over 50,000:1. The actual faceplate illumination is found by the transfer equation:

$$E' = \frac{\pi B \tau}{4F^2}$$

where

E' = Photo cathode illumination (lux)

τ = Optical transmittance of the lens system

F = f/number of lens $\left(\frac{\text{focal length}}{\text{aperture}}\right)$

Using a value of $\tau = 0.7$ and $F = 1$ for the low light level at night, and using $F = 22$ for the lunar day, the photo cathode illumination becomes:

	E'
Day	0.8 lux
Night	0.02 lux

The 50,000:1 brightness ratio has now been reduced by a variable iris to an illumination ratio of 40:1 at the photo cathode. Further reduction of this ratio can be accomplished by one or more of the following means.

1. The use of a higher f stop on the lens, which may not be mechanically feasible.

2. The use of a neutral density filter inserted in the optical path.

3. The use of ALC (Automatic Light Control). This provides automatic control of the tube's operating voltages, causing a variation in the effective sensitivity of the tube.

4. The use of artificial illumination during the night operation.

Each of these methods has certain disadvantages. The insertion of a filter increases the mechanical complexity and may require additional commands from earth if not placed under the control of a local servo loop. Automatic Light Control has been used to control sensitive variations as much as 10,000:1. However, ALC will cause some undesirable effects such as a variation in resolution and lag. Optimum performance then could not be realized over the entire range of light values. The ALC system may also be expected to correct for variation in camera performance caused by temperature variations. The attractiveness of the ALC lies in its all-electronic local feedback nature.

The use of artificial illumination may be required even though the chosen camera is capable of operating with the minimum light levels. Due to the extreme shadows and the peculiar photometric function of the lunar surface, lights may be required for the illumination of obstacles either in the manned or unmanned mode. However, even if available, the more sensitive camera tube minimizes their use, reducing power consumption.

Additional considerations of environment must include the tube's ruggedness to physical shock and vibration, temperature extremes during both the six-month dormant phase and the unmanned operating phase, and size and weight. The latter should be based not only on the tube itself but on the entire camera electronics package. The one-inch magnetically deflected and focussed Vidicon is increased by a factor of 4 or 5 in weight and a factor of 3 in volume when the deflection and focus coils are included. The relative sizes of four camera tubes are shown in Figure 1-1. The weights as given are for the all-magnet type tubes. Hybrid or all-electrostatic tubes would have a slightly greater weight but not as much as the combined weight of the tube, deflection, and focussing coils. Electrostatic models are available in all basic types, but sacrifice some resolution.

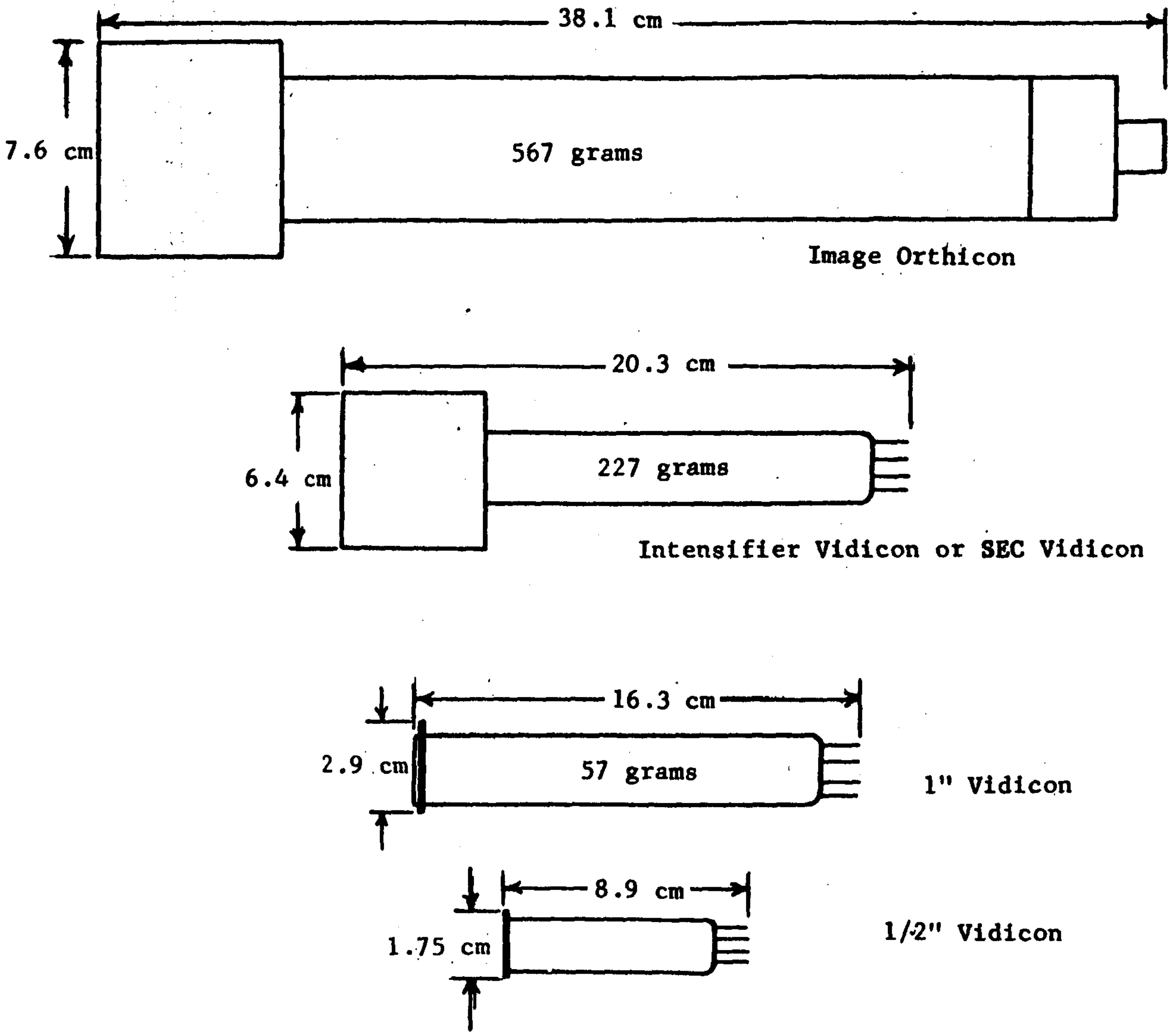


FIGURE 1-1 RELATIVE CAMERA TUBE SIZES

In regard to temperature, the tube, if possible, should be compatible with the existing electronic hardware, avoiding the necessity of maintaining its own special thermal control system. During the dormant phase, the temperature extremes are expected to be greater than in the unmanned roving phase, but the cameras are still expected to be capable of operation during short occasional checkout periods.

Consideration should be given as to whether or not a heating or cooling period must be applied prior to this checkout, although the checkout could be accomplished without requiring optimum performance from the tube due to a non-optimum temperature. The amount of picture degradation due to temperature variation can be catalogued prior to the mission. The temperature extremes where permanent damage occurs must be known.

One further point must be considered in the choice of the camera tube. Since it is expected that stereo operation will be provided for the drive cameras, identical operation must be obtained from the two cameras. A similar problem existed to a greater degree in the three-color camera system where a higher precision in optics and mechanical components and the manufacturing quality of the tube was required.

1.2 GENERAL SENSITIVITY

The sensitivity ratings as given in the manufacturer's data sheets are usually in terms of the faceplate or photocathode illumination (therefore flux density) required for a maximum or for a specified output current. Neuhauser[3] states that: "Light values required for a camera tube are commonly expressed as the intensity of light in foot-candles that is continuously required on the faceplate of a camera tube operating in a standard TV camera system". It is necessary then, for this application, to consider the effects of a nonstandard (slow scan) system and the use of interrupted (shuttered) light. In addition, the scene that is televised to produce the test signal for the rating also should be specified. The specification is often given as a white rectangle on a black background, which then eliminates the aperture response effects or in other words places the operation at the 100% point on the curve. The televising of a more detailed picture causes a reduction in the peak-to-peak video output, according to the aperture response curve and the frequency response characteristics of the amplifier.

In some cases, the light transfer curves used for depicitng sensitivity will be annotated in values of flux (lumens) rather than flux density (in foot-candles or lux). This then assumes a given scanned area which is usually the maximum 4/3 aspect ratio rectangle to fit the tube's diagonal. The conversion then is:

$$\frac{\text{Flux (lumens)}}{\text{Area (sq. in.)}} \times 144 = \text{Flux density (ft.-candles)}$$

In the metric system, with the area in square centimeters, the 144 factor becomes 10^4 and the flux density becomes lux.

In the same paper, Neuhauser relates the camera tube sensitivity to the familiar American Standards Association (ASA) exposure ratings normally used in conjunction with photographic film. This rating is applicable since camera tubes (with the exception of the image dissector) exhibit the storage effect similar to film, the degree of output signal being a function of both the incident light and the amount of time of exposure. The ASA rating for the camera tube is:

$$\text{ASA Exposure Index} \doteq \frac{K}{E_{fp} \times T_f}$$

where:

E_{fp} is the illumination required from highlights

T_f is the field time where open shutter optics are used or the shutter time where interrupted light is used

K is the proportionality constant

$K = 31.2$ with E_{fp} in lux

$K = 2.9$ with E_{fp} in foot-candles

Neuhauser also notes that the value of this rating when the tube is operated in the slow scan mode is useful for the Image Orthicon since its sensitivity is inversely proportional to the scanning rate. However, since the Vidicon has a nonlinear sensitivity relationship to scan time, the rating is useful only within narrow limits. It can be shown that for a Vidicon, the light required is proportional to the 3/2 power of the field frequency[3], and if we assume that at the standard scan rate of 60 fields/second a tube requires 10 lux, then the constant of proportionality is 0.0215. Then the light required at one frame/second would be only 0.0215 lux. This unreasonable figure is based only on the assumption that the tube operating parameters could remain the same, which is entirely false since the target electrode voltage must be reduced to maintain a reasonable dark current. However, as noted in the tests, a greater than linear gain in sensitivity is achieved by reducing the frame rate. Further, when one considers the amount of lag (which does not occur in film) the problem of extrapolating the values obtained from standard rates to low scan rates and including the effect of the shutter is further complicated. The above testing was done with a stationary test pattern.

The ASA Exposure Index system could be useful once a new base figure is established at the low scan rates, and the prediction of the effects of small changes in the parameters is needed. The new base figures would be determined by experimentation rather than mathematics.

1.3 RESOLUTION

The resolving capability of a tube usually will be given in terms of a limiting resolution. This rating is the point where the response at the center of the scanned area is reduced to such a degree that the resulting signal is negligible; it is lost in the noise of the system. A more descriptive picture of the response is seen in the aperture response curve of which a typical curve is shown in Figure 1-2. The curve is the plot of the measured peak-to-peak output signal when imaging a series of test patterns containing a successively greater number of light and dark vertical bars. The output signal usually is normalized to unity at the zero line number. The two curves in the figure represent the relative signal output from the center of the scanned area and the output from a corner of the area when the beam focussing is adjusted for optimum resolution at the center. This loss of resolution at the corners can be reduced somewhat by the use of

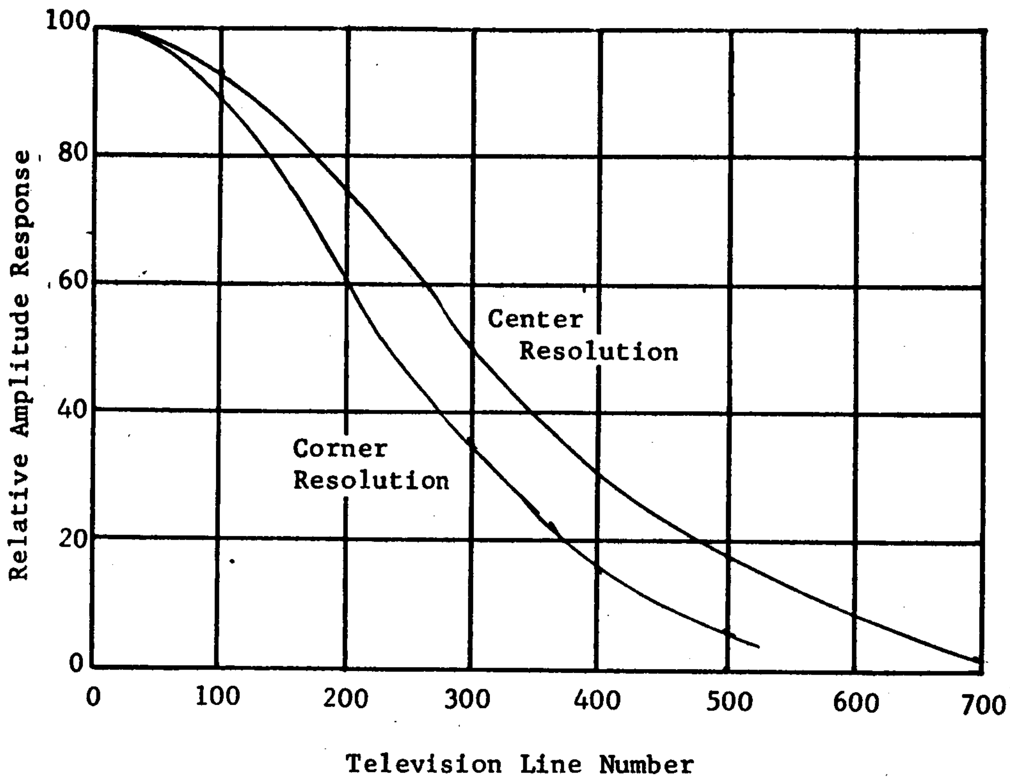


FIGURE 1-2 VARIATION IN RESOLUTION

dynamic focus circuitry if the particular tube is so designed to accept it. Dynamic focus is the addition of a small amount of the horizontal and vertical deflecting voltages, shaped into parabolas and applied to the focussing anode.

It is possible to improve the response of a tube by shaping the response of the associated amplifier. In general this is called aperture correction and is defined as the phase distortionless boosting of the high-frequency components of the video signal. It is done, however, at the sacrifice of the signal-to-noise (S/N) ratio since it boosts the noise as well as the signal. The pick-up device, therefore, must produce a signal with a high intrinsic S/N to the preamplifier. The Vidicon type tube which has this capability and aperture correction is used with good results in these camera types. The Image Orthicon, using an electron multiplier and producing the greatest amount of noise in the low-light areas of the picture, is limited in the amount of aperture correction that it can use.

The ideal aperture correction, therefore the response curve of the amplifier, would be the complement of the aperture response curve of the tube. Notice that the aperture correction still does not extend the limiting resolution figure for the tube.

1.4 LAG

In a slow scan television system, the lag characteristic becomes one of the most important factors to consider. Lag refers to the retention of the image after scanning has been completed. It usually is defined in terms of the percent of image remaining after a single scanning. Additional scans without additional exposure cause a further reduction in the image, usually on an expodential curve. In the open-shutter commercial scanning system, the lag becomes important only when televising fast-moving objects where a certain amount of smear will result. This low amount of lag is due to the relatively large number of scans that will occur per unit time.

Consider now the peculiar application of the vehicle television cameras where the frame rate must necessarily be limited (in order to conserve bandwidth and therefore transmitter power) to less than 5 frames/second. In the proposed conceptual design, a frame rate of one and an exposure time of five milliseconds was selected. The frame rate is based on bandwidth limitations and the exposure time to prevent image smear in the worst case condition of a turn. The photo cathode then is exposed to a five millisecond pulse of light which will result in a stored charge to be discharged as much as one second later. The discharge of the image must be fairly complete or the residual image will appear in the following cycle or cycles. The degree of retention of the image that can be tolerated must necessarily be a function of the particular application of the system and should be investigated under simulated conditions of the application.

1.5 DYNAMIC RANGE

The dynamic range of the camera tube is a number to express its ability to handle wide ranges of light levels without readjustment of an operating potential. This value is defined as: "the ratio of the maximum signal that the target can store without saturating to the minimum detectable signal". Its value is a measure of the ability of the target to successfully portray scenes containing highlights as well as shadows.[15]

The necessity for a wide dynamic range is much greater for the cameras on the lunar surface than it would be in a studio where the lighting is carefully and continuously controlled to eliminate the deep shadows. A camera on the lunar surface, at a height of two meters and depressed 20°, panned through an angle of 180°, observes a scene whose brightness varies from a maximum of 3105 candles/m^2 to a minimum of 203 candles/m^2. This is based on a constant albedo of seven percent. If variation in albedo also was considered, the ratio would be higher than the 15:1 value.

1.6 GAMMA

Gamma is defined as the slope of the light transfer curve of a particular tube, expressed mathematically as:[11]

$$I_s = E_i^{\gamma}$$

where:

I_s is the signal output

E_i is the incident illumination on the faceplate

γ is the equalizing exponent

The ideal gamma of a camera tube would be that value that would just complement the gamma of the output device, the picture tube. The picture tube's gamma usually has a value of approximately 2.5, dictating an ideal gamma of 1/2.5 or 0.4 for the camera tube. The gamma of the Vidicon will range from 0.6 to 0.9, depending on the target material; but more important is the fact that it is relatively constant over a wide range of operating potentials and light values. Since it is predictable, it can be compensated for by a gamma correction circuit.

The Image Orthicon's gamma will depend on the point of operation on the light transfer curve. When the highlights are just allowed to reach the knee of the curve, the gamma is then quite high. If the lens is opened one or two stops above this point, the gamma is reduced to about 0.65. However, this means a reduction in sensitivity by a factor of four.

The gamma for the SEC Vidicon is reported as unity but the tube does not have the limiting point characteristic of the Image Orthicon and the gamma; therefore, it can be corrected by the associated circuitry.

1.7 VIDICON

The Vidicon is characterized by its small size, ruggedness, high intrinsic signal-to-noise ratio, good resolution, and reasonable power supply requirements. Physically, it best meets the requirements of the space environment. The points in question regarding its use are the relatively low sensitivity and the high degree of lag that occurs when the tube's parameters are adjusted for maximum sensitivity.

The main controlling parameter in the operation of the Vidicon is the signal electrode or target voltage. To best illustrate the effects when varying this voltage, the combined diagram of Figure 1-3 is used. The

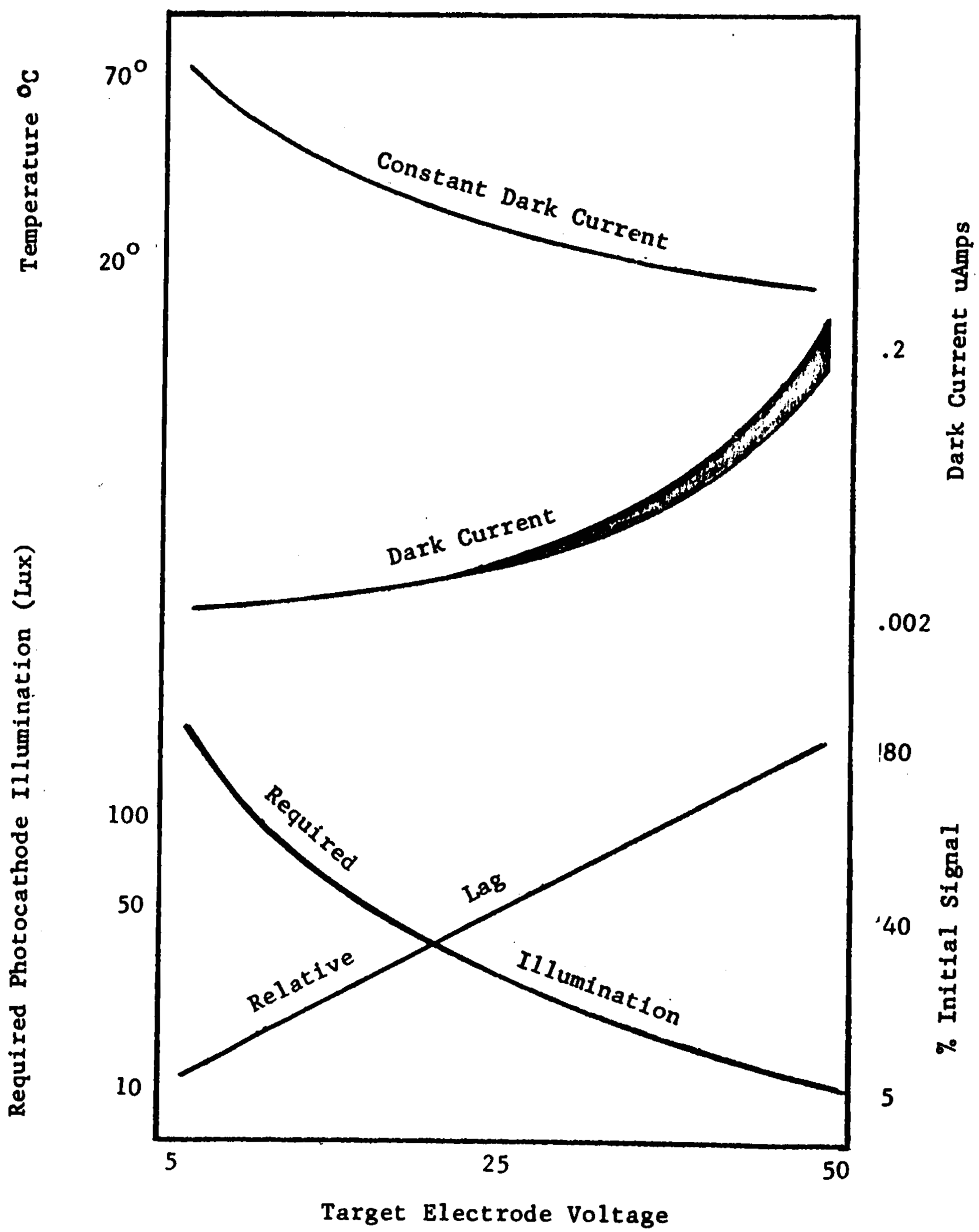


FIGURE 1-3 EFFECT OF VARIATION IN TARGET ELECTRODE VOLTAGE

lower two curves show the important reverse relation between sensitivity and the percentage of lag. Operation at the higher target voltages provides the maximum sensitivity, however, with the corresponding increase in lag. Secondly, then, we see the expodential rise in dark current. The maximum sensitivity operation of the Vidicon may be either the point of intolerable lag which will depend on the type of intended operation, or the point at which the dark current becomes excessive.

Dark current is defined as the current flowing in the signal electrode in the absence of any faceplate illumination. As long as the dark current is constant over the entire scanned surface, the resulting direct current component may be blocked from the signal component and therefore ignored. However, at high signal electrode voltages and/or a high operating temperature, the high dark current becomes non-uniform over the entire surface, and the resulting a.c. component appears as an objectionable shading. The point at which this shading becomes sizable as compared to the low lights then sets an upper limit to the signal electrode voltage and, therefore, a limit on the sensitivity. In any given tube, the ratio of the a.c. component to the average value of the dark current is a function of the target uniformity and should be relatively constant. The responsibility of the construction of a high sensitivity tube then lies in the manufacturer's quality control of the target so that the tube may be operated at a high average dark current, therefore reducing the aforementioned ratio.

The upper curve in Figure 1-3 finally shows the effect of temperature on the tube operation. To maintain the same dark current, the signal electrode voltage must be reduced as the operating temperature increases. The sensitivity, therefore, is inversely proportional to the temperature. The desirable operation is then at a low stabilized temperature. Figure 1-4 shows actual illumination required for a given signal current.

Operation at low signal electrode voltage provides a "fast" and stable camera operation. The lower limit of this control voltage is the improper beam landing that occurs in the corners of the raster. This effect occurs at approximately + 5 v on the target while a signal is generated only in the center of the picture.

1.7.1 VIDICON SIGNAL-TO-NOISE

It usually is assumed that the noise generated within the Vidicon is small when compared to that contributed by the first stage of the associated preamplifier. In order to provide aperture correction, and in an attempt to equalize the response for increasing frequency, the amplifier becomes a high peaked circuit. Then the signal-to-noise ratio usually is given as 100:1 (peak-to-peak signal to rms noise) or as 300:1 visual equivalent signal-to-noise. This is obtained with a cascade (low noise) amplifier at the recommended highlight signal output of 0.35 uAmps. Therefore the equivalent noise current at the input of the amplifier was 0.35/100 or 0.0035 uAmps. The term "visual equivalent signal-to-noise ratio" was coined by Neuhauser[11] where the 3x gain is due to eye tolerance to high frequency noise.

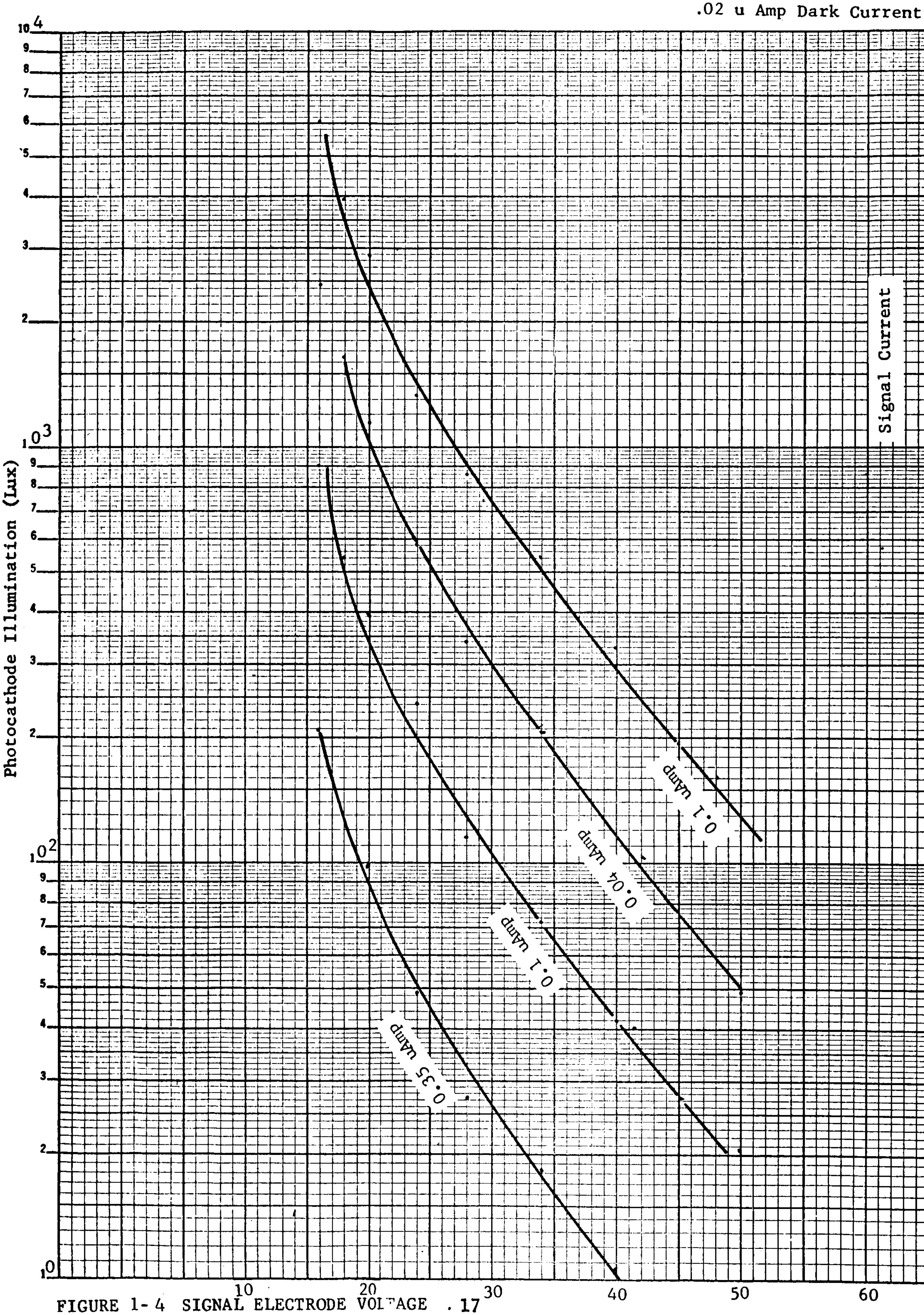


FIGURE 1- 4 SIGNAL ELECTRODE VOLTAGE . 17

1.7.2 OPERATION OF THE VIDICON AT SLOW SCANNING SPEEDS

In general, operation of the Vidicon at slower than standard scanning speeds will:

1. Show a slight increase in the resolution capabilities.

2. Present an appreciable gain in the sensitivity of the device for the same signal-to-noise ratio.

3. Provide a reduced problem in the lag characteristic.

4. Show a loss of dynamic contrast range at the lower rates.

In Figure 1-5, the results of the experimental work done by Shelton and Stewart[5] in their operation of a Vidicon at slow scanning rates is shown. The graph is a collection of data taken from several graphs in the paper, with the tests being made with a constant number of scanning lines while the frame rate is varied between four discrete values. Under these conditions then, the bandwidth and the noise current is reduced proportionately to the frame rate. The constant signal-to-noise ratio curves deviating from the vertical show the increase in sensitivity that is achieved at the slower scanning rates. The increase is much less than the theoretical maximum that could be achieved. The high theoretical gain is based on the idea that the Vidicon will produce a constant output signal regardless of scanning time and that the noise is directly proportional to the bandwidth. Therefore as the frame rate is reduced, the sensitivity is inversely proportional to the frame rate. The false assumption involved in this conclusion is that the tube operating conditions can

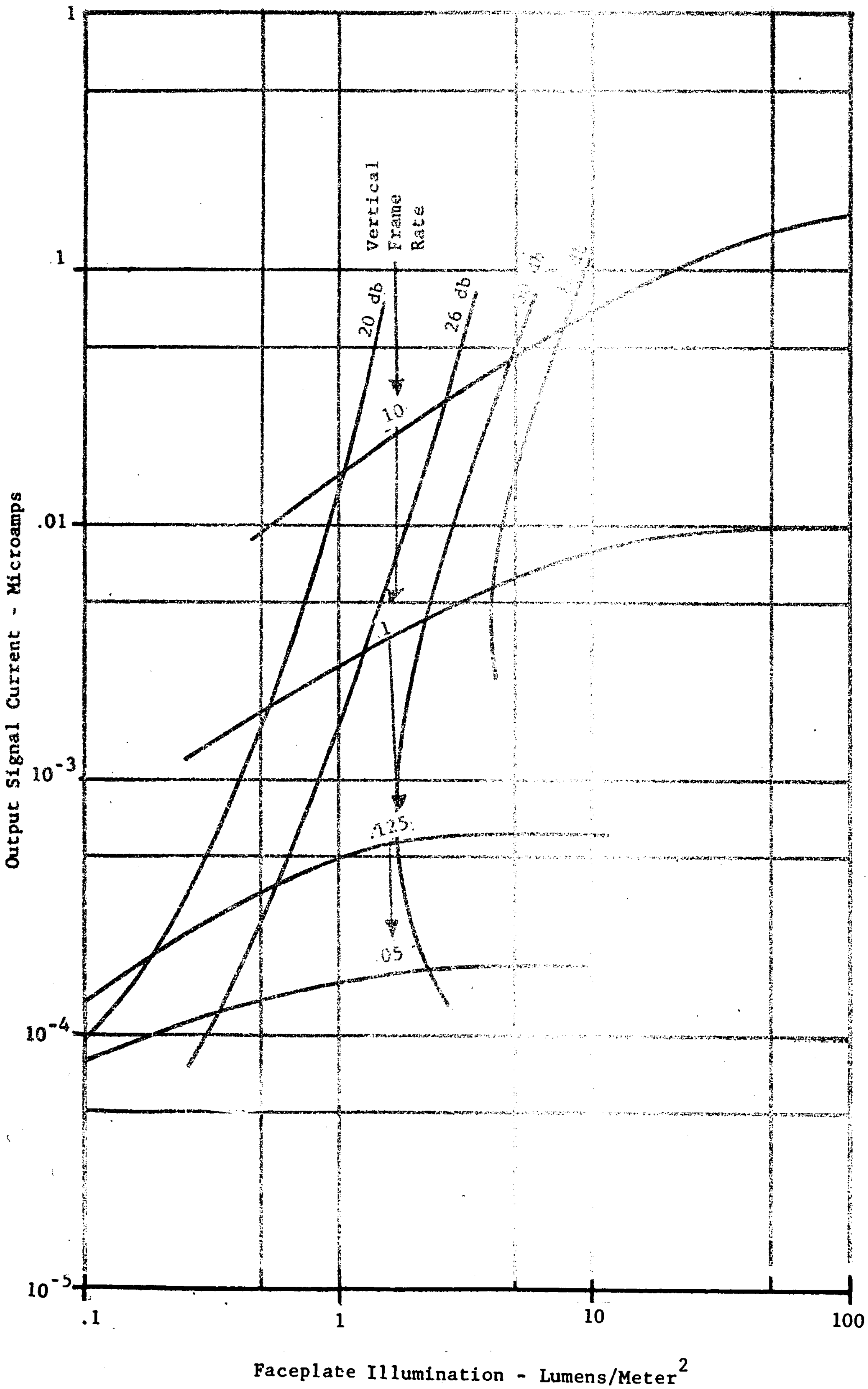


FIGURE [illegible] VIDICON SLOW SCAN SENSITIVITY remain the same. In actuality, the dark current will increase due to the slower scanning and the variation in the dark current may become a significant part of the output signal. To counteract this effect and keep the ratio of signal current to dark current within reason, the signal electrode voltage must be reduced as the frame rate is decreased, yielding a corresponding decrease in sensitivity.

Another fallacy in the curves as mentioned in the report is due to the testing procedure. The tests were made using an Image Orthicon type of preamplifier which has a relatively flat frequency response instead of the normal Vidicon low-noise first stage and high frequency peaking (aperture correction). In the I.O. (Image Orthicon) preamplifier, the noise reduces linearly and in the Vidicon preamplifier the noise would be reduced expodentially. Because of this, the noise values used at the lower frame rates are somewhat high, making the constant signal-to-noise lines intersect the light transfer curves at higher illumination values than the theoretical.

It also should be remembered that the type Vidicon selected is not characteristic of the newer types now available that can be operated at a much higher dark current (by a factor of ten). Remembering that it is not the high average values in the dark current that limits the operation, but the variations that exist due to non-uniformities in the target, future manufacturing techniques can result in higher sensitivities.

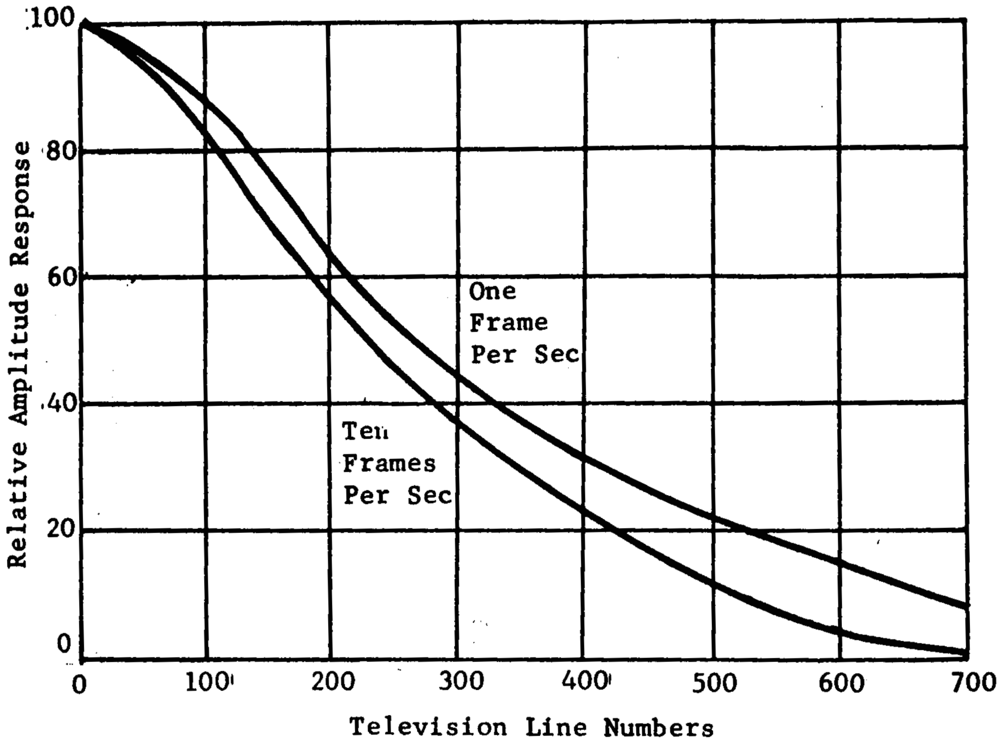
The loss in dynamic range also is apparent by noticing the increased flattening of the curves as the frame rate is decreased. This again is due to the required decrease in signal electrode voltage causing saturation of the target by the highlights. The limitation occurs when the signal voltage becomes a large part of the signal electrode voltage, which should be as severe in the newer types operated at a higher dark current and a higher signal electrode voltage.

1.7.3 RESOLUTION WITH SLOW SCAN

The resolution of the Vidicon is only a function of the dimensions and the shape of the scanning beam itself.[11] The increase in resolution that occurs at the lower frame rates is due to a reduction in the beam size at the lower beam currents that are used. Figure 1-6 depicts the resulting plots of aperture response curves as measured by Shelton and Stewart[5]. These curves show the increase in limiting resolution that occurs when the frame rate is changed from 10 frames/second to one frame/second. At 500 lines resolution (the probable value for this application), the response increases from 10 to 20 percent.

1.8 IMAGE ORTHICON

The high sensitivity of the Image Orthicon makes its choice hard to ignore when considering the low illumination levels on the lunar surface. By using an image intensifier having a gain of 50, the overall sensitivity rating can be based on a 10^{-7} lumens/m^2 faceplate requirement. The penalty paid for this high sensitivity should be evaluated before going to the simpler pickup devices.



FRAME RATE EFFECT ON RESOLUTION

FIGURE 1-6 APERTURE RESPONSE CURVES
(Taken from Shelton and Stewart,
Pickup Tube Performance with Slow Scanning Rates)

The first point of consideration is the high comparitive complexity of the Image Orthicon which becomes salient when considering remotely controlled operation. The simple I. O. (no intensifier) has fifteen applied potentials, not considering deflection or focus currents, of which seven usually are made adjustable. Compared to this, the Vidicon has six applied potentials of which three are made variable. The potentials themselves cover a range of 1800 volts for the I. O. while the Vidicon requires approximately 400 volts for operation.

All-electrostatic models of the Image Orthicon have been constructed, but these would still be four times heavier than the comparable Vidicon, while the volumetric ratio would be approximately 22.5:1. The increased circuitry necessary for the I. O. includes extra controls, the bleeder networks, and a high voltage power supply for the electron multiplier. This is not considered excessive as is; however, when one considers that the extra controls may require one servo loop each for the remote operation, the additional size and weight becomes appreciable.

When sensitivity ratings are given for the Image Orthicon, the actual point of operation in reference to the knee of the light transfer curve must be specified. In Figure 1-6, the curves of several tubes have been shown. Depending on the type of operation desired, the "highlights" may be placed at the knee of the curve, or one or two "stops" above the knee. For example, the 5820 curve shows the knee at 0.2 lux while highlights at two stops above the knee are 0.8 lux on the photocathode. Descriptive literature, however, will say the tube can produce signal information 10^{-3} lux on the photocathode. Operation at one or two stops above the knee is desired in broadcast operations (except colorcasting) due to the aesthetical value of the contrast enhancement that occurs in this type of operation[4]. For this application, operation with the highlights just reaching the knee of the curve would be more desirable, and would provide a more realistic picture.

1.8.1 SLOW SCAN OPERATION

In Figures 1-7a and 7c, the results of tests made by Shelton and Stewart[5] when operating a 5820 Image Orthicon at slow scan rates are shown. The light transfer curves of 1-7a show the loss of the highly defined knee when compared to Figure 1-6. The knee also shows a shift to the left as the frame rate is reduced, indicating saturation at a lower light level. In Figure 1-7c, the increase in sensitivity can be seen. The required light level indicated is based on that value necessary to produce a signal-to-noise ratio of ten. The curve would be more linear at the lower frame rates, and therefore would show a greater sensitivity, if the equipment with which the tests were made was designed for a particular frame rate. As pointed out by Shelton and Stewart, the amount of light required is directly proportional to the frame rate (for a constant S/N and a constant number of scan lines), and this theoretical increase could be more closely approached if the equipment and the tube itself were considered.

Figure 1-7b shows the effect of target temperature on the resolution. The curve indicates the maximum temperature before degradation of picture quality. This variation is due to the increase in target conductance at the higher temperatures which possibly could be controlled in the manufacture of a special tube.

FIGURE 1-7 IMAGE ORTHICON OPERATED IN SLOW SCAN MODE

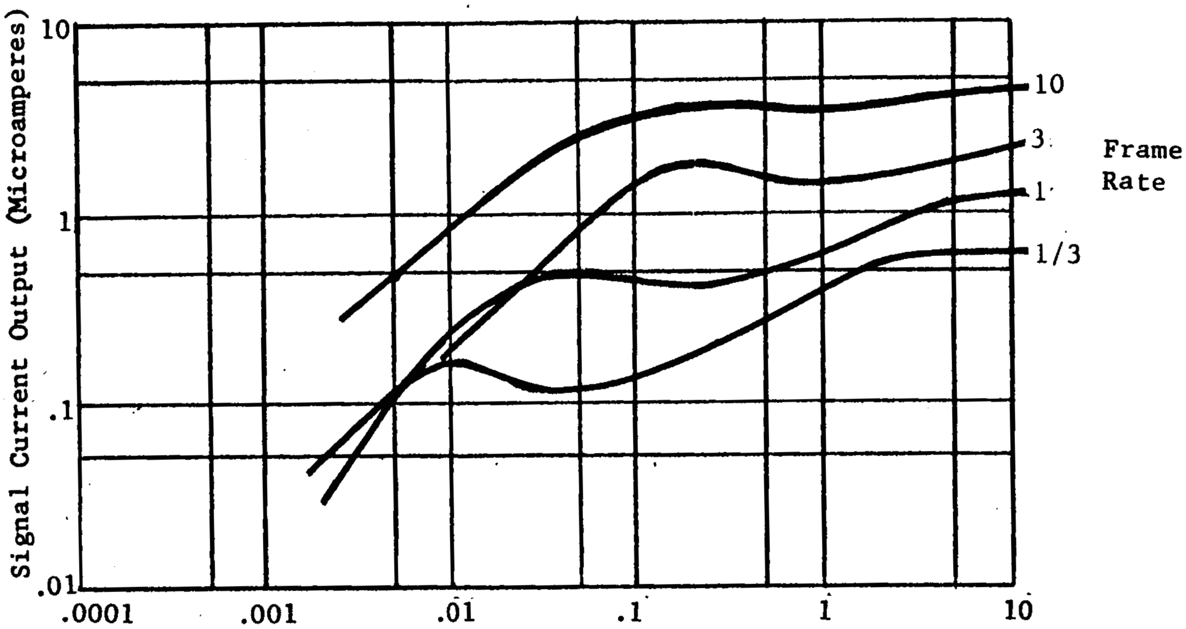


Figure 1-7a Image Orthicon Light Transfer Curves at Slow Scan Rates

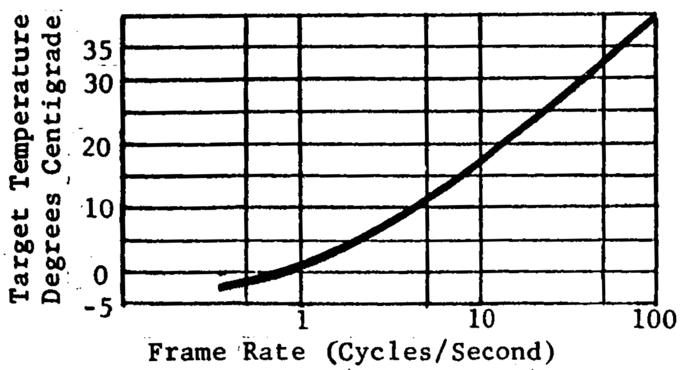


Figure 1-7b Temperature Effect on Resolution

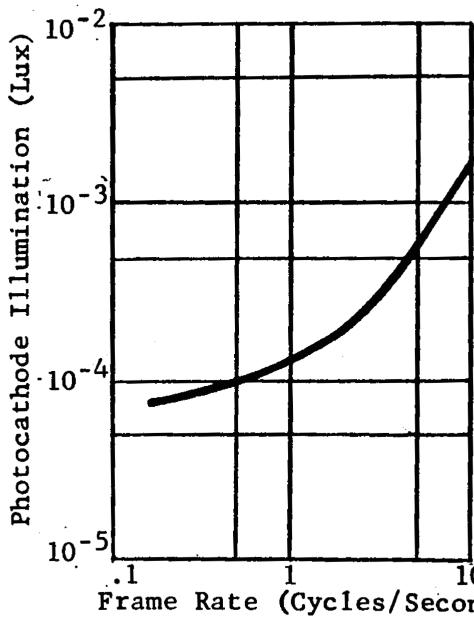


Figure 1-7c Slow Scan Sensitivity

Note: Figure 7c and data for Figures 7a and 7b taken from Shelton and Stewart[5]

Temperature sensitivity of the Image Orthicon in general is greater than that of the Vidicon. In the Vidicon, a rise in temperature is compensated for by decreasing the signal electrode voltage accompanied by a corresponding decrease in the sensitivity. Variation in the Image Orthicon temperature will show an appreciable decrease in resolution at the higher temperatures, and an increased lag at too low a temperature.

None of the above can be considered as an insurmountable obstacle preventing the use of the Image Orthicon. However, when considering the accelerating, vibrational, and shock forces that the camera will be subjected to during the launch and landing of the vehicle, one looks for test data in these areas. The lack of such data and the study of the construction of the Image Orthicon is indicative of the weakness of the tube for operation under hazardous conditions. The physical weak point of the tube is the target assembly which consists of a glass membrane, 2-1/2 inches in diameter, and 0.0002 inches thick, supported by a metal ring. Place in front of the target at a distance of 0.001 to 0.003 inches is a mesh screen. The uniformity of the separation of the two and the "flatness" of the glass is critical to the quality of the resulting picture. The structure is sensitive to vibration such that a high speed blower operating near the tube could introduce an a.c. component into the signal. A more rugged verison of the Image Orthicon has been built to reduce the vibrational sensitivity. At the cost of a reduced signal-to-noise ratio and reduced dynamic range, the target-to-mesh distance was increased from 0.001 to 0.0025 inches. The amount of displacement of mesh due to vibration is now a smaller percentage of the total distance, and the a.c. component introduced into the output by vibration is proportionately less. Figure 1-6 shows the reduction in the dynamic range with the knee of the curve at the

3 uAmp signal level. Tests with an experimental Image Orthicon where the target-mesh spacing was increased to 0.150 inches caused a large deviation from the typical I.O. curve. The sharp saturation points were not as apparent, allowing a greater dynamic range; however, the transfer curve was no longer linear. The signal-to-noise ratio of both wide-spaced tubes is as much as 35 db less than the narrow-spaced tube.

1.9 SEC VIDICON

The Secondary Electron Conduction Vidicon is a pickup tube designed to overcome the two limiting characteristics of the Vidicon while attempting to maintain the desirable Vidicon features of compactness, ruggedness, high resolution, good intrinsic signal-to-noise ratio, and the low demanding power supply requirements. The two limiting characteristics of the Vidicon were the relatively low sensitivity and the high degree of lag occuring with the tube operated in its maximum sensitivity mode.

The Westinghouse SEC Vidicon consists of a photocathode producing an electron image which is accelerated to impinge on the SEC target. The total image gain or the gain before scanning is given as 300, making the tube approximately 300 times as sensitive as the simple Vidicon. The target is scanned from the opposite side by a Vidicon type gun using direct beam readout, although the feasibility of return beam scanning with an electron multiplier is being considered.

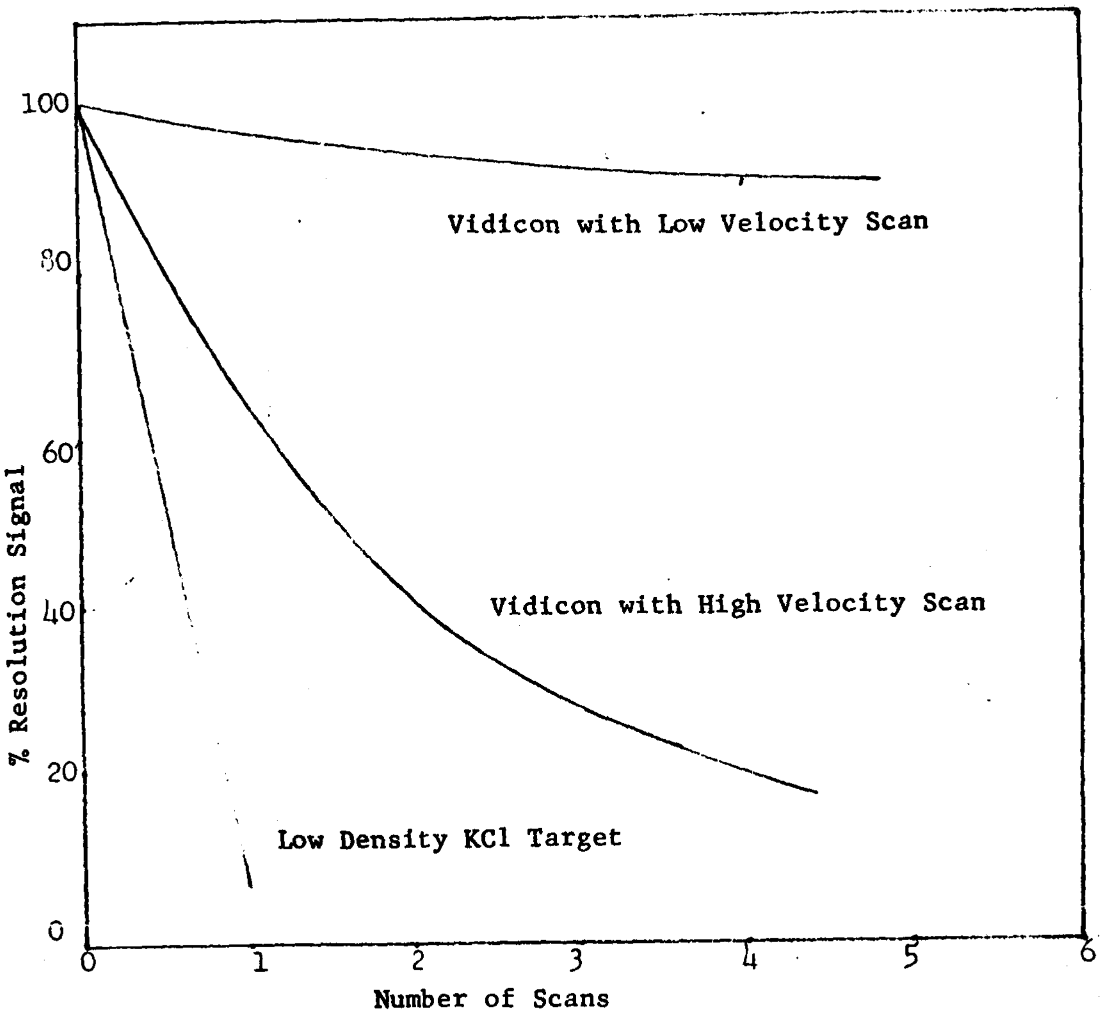
The resolution capabilities are limited by the image accelerator portion of the tube indicating that the resolution would be lower than that of a

Vidicon which does not have a similar component. The limiting resolution of the present tubes is 600 lines, which is marginal for this application. Aperture correction is feasible due to the high intrinsic signal-to-noise ratio, but would not apply if the return beam electron multiplier were used. No degradation of resolution occurs because of the shadowing effect of a mesh in front of the target such as is in the Image Orthicon.

In the Vidicon, a slight increase in resolution was seen when the scanning rate was decreased. However, the resolution in the simple Vidicon is a function of the beam current and shape which are reduced at the lower rates. The SEC Vidicon resolution is not a function of these factors so it is questionable as to whether or not a similar increase will appear at the lower scanning rates.

The image section of the tube requires an accelerating potential of eight kv, which takes it out of the class of the simple Vidicon that required approximately 400 volts for operation. The deflection and focussing potentials would approximate those of the Vidicon.

The SEC Vidicon can operate with a wide dynamic range of 100 or more without a readjustment of the beam current. This is on a par with the simple Vidicon and is much better than the Image Orthicon which has a dynamic range of 18 at the most without a readjustment of the beam current. In addition, automatic light control is feasible when similar to the Vidicon but unlike the Image Orthicon.



Residual signal as a function of number of scans for a Vidicon and for a tube with a low density KCl target.

Note: This diagram taken from Reference 15, Westinghouse proposal.

FIGURE 1-8 COMPARATIVE LAG

The second prominent disadvantage of the Vidicon other than sensitivity is its tendency to have a high degree of lag when operated at a high target voltage for maximum sensitivity. This deficiency becomes more apparent when operated in shuttered slow-scan operation without an erase cycle. Figure 1-8 compares the simple Vidicon and the SEC Vidicon in regard to this characteristic. Westinghouse describes this operation as the "most unique single characteristic of the SEC target". The curves for the Vidicon are probably not a true representation of the latest designs for slow-scan operation. When operated at standard scan rates, 60 fields per second interlaced with beam overlap, the target is scanned 12 times in 0.2 seconds --- the normal retentivity value for the eye.

The main point of limitation in the use of the SEC Vidicon would be its ability to withstand the acceleration, vibration, and shock environment of the Saturn V launch and the lunar landing. No data is presented on this phase of the tube's tests. However, some conclusions can be drawn by considering the tube's construction.

The weakest point is the physical construction of the tube would be the target and its mounting. The target consists of an aluminum oxide film of about 1000 Å (0.1 microns, 3.9×10^{-6} inches) thickness, covered by a layer of aluminum 500 Å thick, coated by a third layer of KCl 25 microns thick, but having a very low density. The entire target then is supported by the aluminum oxide film attached at its periphery to a Kovar ring. The diameter of this target is approximately one inch and it is questionable as to whether or not the target structure could withstand a large magnitude shock.

The SEC Vidicon then possesses all the desired features for a camera tube operated under the shuttered, slow-scan, high resolution conditions with the exception of a lack of ruggedness and with the requirement of a high voltage supply. The almost complete discharge of the image after a single scan, and its relatively high sensitivity with the probable operating conditions make it the most attractive of the tubes. Tubes having electrostatic deflection and focus have been built and provide substantial weight and size savings.

The Image Orthicon's high sensitivity is overshadowed by its complexity and low dynamic range. New developments in ruggedized tubes may bring it to the point that it could withstand the hostile environment of the lunar trip; however, data on this phase is conspicuously absent. In regard to the high sensitivity, R. A. Lee[15], states, "With the same photocathode sensitivities and active areas, Image Orthicons are three to ten times more sensitive than SEC Vidicon when operated with continuous faceplate illumination and at 30 frames/second. However, when using single shuttered exposure or when there is significant motion in the image, the SEC Vidicon becomes more sensitive than the Image Orthicon."

Since shuttered exposure is the type of operation that is required here, the Image Orthicon and especially the Vidicon would require operation in their least sensitive mode to prevent stickiness or lag in the pictures.

The SEC Vidicon is chosen for this particular application contingent to its ability to withstand the adverse environment.

2.0 EARTH STATION

2.1 INTRODUCTION

The final design of the earth station, from which the remote driving of the lunar vehicle will take place, will be the result of extensive simulations made under conditions that closely approximate the actual problem. The conditions of simulation are:

1. The vehicle should match the actual MOLAB physical dimensions and locomotion characteristics.

2. The driving surface should simulate the lunar terrain according to data obtained from the Ranger and Surveyor missions.

3. An actual control station with an artificial delay system should simulate the earth-moon transmission delay.

The purpose of this section, then, is to:

1. Investigate the information that will be available via television, telemetry, and data derived from these sources.

2. Investigate information that can be obtained from the commands being sent to the vehicle.

3. Formulate a presentation system of this data to act as an initial system, to be modified on suggestion of the drivers as they conduct their testing and training program.

The function of the drive station could be divided into three phases during the mission. In the unloading phase, the MOLAB will be controlled from the station through the use of television. This control procedure should be relatively simple. In the unmanned driving phase, the station will function in its most demanding role, and should be designed to accommodate the required conditions. In the third phase, the manned MOLAB stage, the station becomes more of a data collection and monitoring point with the possibility of acting as primary control of the MOLAB under emergency conditions.

It is assumed at this time that two television cameras aboard the MOLAB are relegated to the remote driving task. A third camera might provide a rear view on command of the driver. The two forward-looking cameras are provided for redundancy, but the way that they are used under normal conditions has not been firmed. The choice of methods could be selected from the following:

1. Only one camera is operated at a time with the other in a standby condition. The single camera would be operated at twice the frame rate, slightly reducing the delay time in the control servo loop. Conservation of camera operation time also could be provided, if this were considered a problem.

2. Both the cameras are operated as a stereo pair. In tests using a lunar model, M. E. Amdursky[6], senior staff engineer, Bendix Systems Division, states, "If provisions for stereo techniques can be accommodated at all on such missions, they should be included". The cameras would be simultaneously exposed for proper registration, and then read sequentially. The disadvantage in the use of this stereo system

lies in the fact that the frame rate is reduced by two when compared to system 1.

3. The cameras are operated in a bifocal system with one camera viewing through a short focal length lens and the other through a variable focal length normally set at a long focal length. The value of such a system would be that the driver, using the short focal length camera, would be avoiding the present obstacles, while a second driver viewing the more distant terrain could investigate the future problems and decide the overall course. The same information could be obtained by the other systems at the penalty of stop-and-go driving techniques. In this mode, the two cameras would not have to be exposed simultaneously as in stereo operation.

4. The two cameras are so oriented as to provide the maximum horizontal field of view. The cameras would view areas side-by-side, possibly with some overlap. Simultaneous exposure might be desirable, but would not be considered absolutely necessary.

5. Bi-color operation is not considered feasible, but is included for completeness.

The probable choice of operation will result in the selection of either system 2, 3, or 4, each of which has desirable features. M. B. Amdursky[6], states, regarding stereo, "The pits and depressions likely to be found at ground level observation are all but invisible using non-stereo techniques --- but the same view on a stereo basis shows them clearly".

The advantages in the bifocal system (system 2), are that some of the pressure is taken off the primary driver and that a certain amount of planning occurs in this system which would not appear in the others. This could have a great deal of significance in regard to power consumption.

The third system, providing the maximum horizontal field-of-view, is included in reference to a comment made by the test subjects after an experimental program of driving by television which included a long delay in the control loop. (See Reference 3, page 66.) "Both the drivers feel that their performances are adversely affected by not having a wider viewing angle." The effects of the present 53° viewing angle are described in the maze experiment discussion. It is strongly recommended that means for increasing the angle of vision be considered and used, if possible, in future studies.

It is felt that this complaint, at least in part, is psychological in that a driver in the car enjoys approximately 180° horizontal field-of-view without turning his head. The drivers of the test vehicles were possibly worried about what was coming toward them from the side streets. Extensive training could alleviate this fear and let them accept the mathematically determined narrower field of view. Therefore the selection should be between systems 2 and 3, and the final determination made by drivers in a closely simulated system.

2.2 THE VIDEO DISPLAY

There should be no problem for the display of system 3, bifocal operation. The CRT (cathode-ray tube) displaying the far view could be mounted above the near view, with the secondary operator standing behind the driver. Both men, of course, would have viewing capability of both displays.

There is some area of choice in the presentation of stereo television as seen in Figure 2-1. The three systems illustrated each have certain advantages and disadvantages. The system employing the color tube has the registration and convergence problems inherent to the color tube; the red display appears black through the red filter with the blue display being highly attenuated. The same problem applies for the other eye with only the blue display being seen. This system has been used by Bendix in certain experiments.

The Polaroid system would be the simplist mechanically, although the image intensity is lessened considerably and dual monochrome CRT's are required. A higher attenuation of the unwanted image could be achieved with this system.

The attenuation of light by filters in the other two systems is eliminated by the use of the motor driven shutter in the third system. Alternate left and right video is displayed on the one CRT with the shutter passing the proper display to either eye. The shutter must be synchronized to the vertical frame rate of the scan converted video and a phasing adjustment is necessary in the motor control.

The last two systems were demonstrated in 1955 at the American Television Institute, Chicago. In all three systems, it is recommended that the CRT's display a normal 60 fields/second as delivered by the scan converter from its 1/2 to 5 frames/second input.

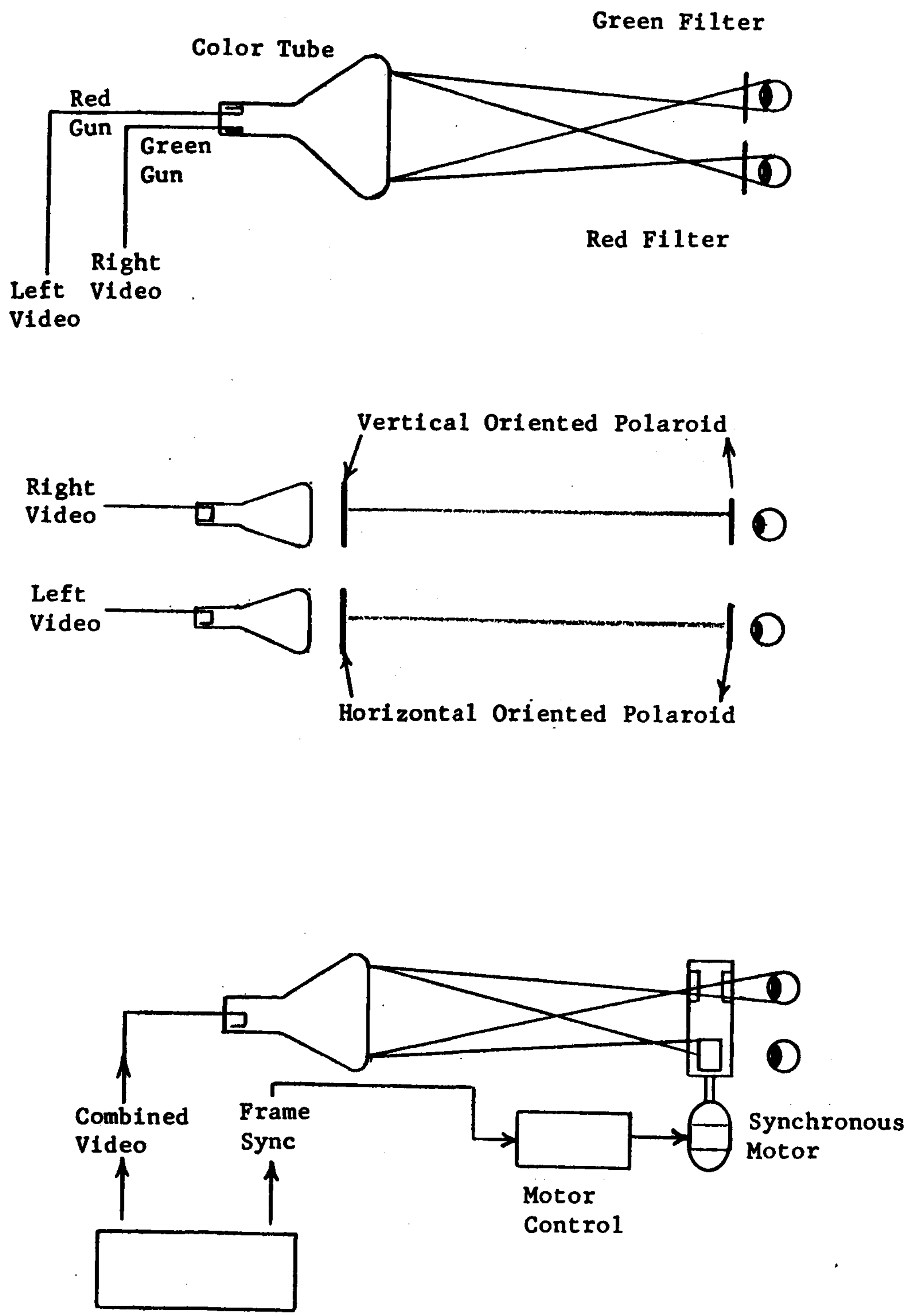


FIGURE 2-1 STEREO TELEVISION SYSTEMS

If the choice of a system were to be made at this time without the benefit of objective testing, the Polaroid system would be selected. The resolution capabilities of the present color tubes would not meet the criteria of the problem. The side-by-side CRT's, however, would cause the driver to focus at a distance farther than the plane of the display panel, which might cause some fatigue if he were required to shift his view to instruments mounted beside the panel. This problem could be solved by optically superimposing the two images as in Figure 2-2. In this solution, only one CRT is illuminated at a time, and they alternate at a 60 cps rate.

2.3 SECONDARY DISPLAYED DATA

Through telemetry, additional data can be made available to the driver. This data should be sorted as to its importance and displayed accordingly. The driver should not be encumbered directly with such functions as power management and overall course, but should be concerned only with such data that aids him in obstacle avoidance. A second driver, coordinator, or planner will analyze the overall progress and future goals, and feed such data as necessary to the driver.

Of primary importance to the driver describing the vehicle dynamics would be the vehicle velocity and the turn angle or wheel angle. In order to provide the driver with a more realistic feeling for the velocity, an audible tone could be used as an indication of the speed. The tone would be generated by a variable frequency oscillator whose frequency is proportional to the velocity. A visual indicator of velocity would be avaliable also, but should be used only as a confidence device, since its use would require that

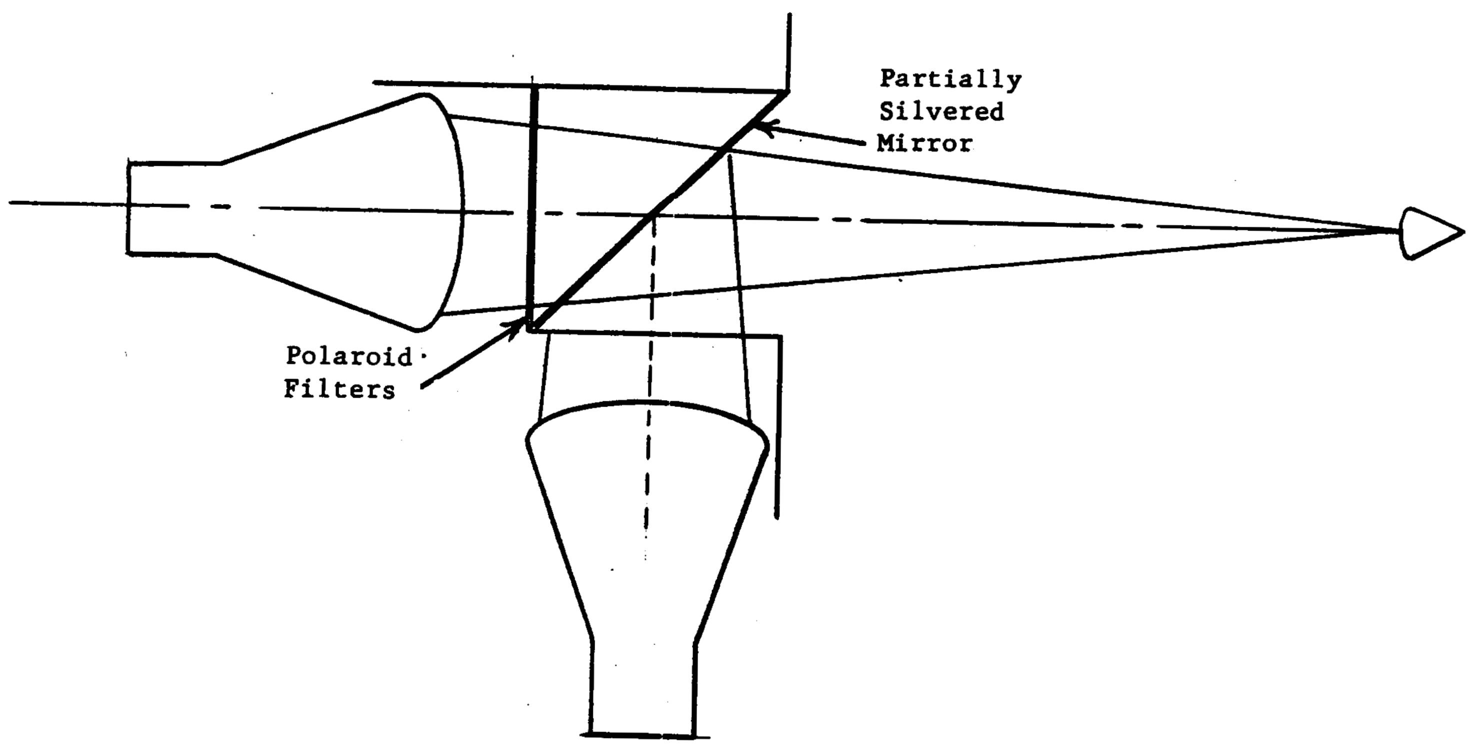


FIGURE 2-2 SUPERPOSITION OF IMAGES

the driver's eyes shift from time to time off the video display. The actual value of the velocity data may be obtained from telemetry, however, lagging in time by 1.3 seconds, or a synthetic value may be taken from the commanded value and delayed 1.3 seconds to coordinate its value with the vehicle's actual speed. The delay, therefore, puts it in real time. The visual display should indicate both values on a dual meter such as is shown in Figure 2-5; however, the audio indication should show the delayed commanded value.

The turn angle should be treated in the same manner although no audible indication of turning is provided. A dual meter again is used to show the commanded value delayed artificially and the received value (actual) which is unavoidably delayed. For both velocity and turn angle, the two values should indicate the same, except for a 1.3 second period following the actual movement of the vehicle. For example, the driver commands a right turn. One and three-tenths seconds later the vehicle actually executes a right turn and the commanded value meter swings proportionately to the right. After another delay of 1.3 seconds, the true turn angle is received via the telemetry and is shown on the other meter which now swings to match the first meter.

Additional indicators available to the driver will denote the television camera angles (azimuth and elevation) and the focal length of the lens, assuming that a variable focal length type is used. The actual azimuth angle of the cameras will be that of wheel turn angle, allowing the driver to "see" in the direction he is turning, and also reducing the smear problem. Additional camera panning is allowed through a control and this angle should be displayed as the deviation from the normal, i.e., the angle plus or minus the wheel angle. A nominal depression angle will also be determined with an additional capability of deviating from this normal. The deviation will be displayed. The orientation of the meters should be indicative of the actual action involved.

A nominal value will be used for the focal length with a control and indicator of telemetered value to cause and indicate deviations from this nominal value. If a turret lens system is used, warning lights can alert the driver that the wrong lens for driving is being used.

2.4 PREDICTOR

The use of a predictor or anticipator is considered highly desirable for any control system containing a long delay. It is shown in tests[18,19,21] that the tracking ability of a system with a delay and using a predictor can approach that of a system not containing a delay. In general, a predictor will provide an immediate display of the effects of a command that the operator may insert into the system. Without such aid, the driver does not see the effect of a command that he has applied until twice the earth-moon delay time has elapsed. The effect of this delay in feedback information causes the driver to overshoot and oscillate about a desired trajectory. Even disregarding the probable loss of the vehicle, the increased power consumption decreases the overall of a successful mission.

The additions to the system, for the predictor, will require a small analog computer with trigonometrical function capabilities and some form of video generator to convert the d.c. outputs of the computer to a format presentable on the monitor. The computer portion will accept as input the turn angle as commanded by the operator and will produce an extrapolated theoretical future point as a function of this angle and time. The display portion of the unit accepts this output and produces video outputs representing the future data. This video data is then mixed with the video from the vehicle cameras and is displayed on the monitor.

It is desirable that the predictor show basically two forms of information: the effect of an inserted turn, and the projected width of the vehicle on the terrain in front of the vehicle. The final design of the computer and the display unit will depend on the vehicle dynamics, the type of steering used, camera perspectives, etc.

One form of display generator is described by Arnold and Braisted[20], and uses an X-Y recorder with the substitution of a marker for the pen. The marker is positioned according to the computer outputs and represents the extrapolated future position. The recorder is televised by a camera positioned to give the same perspective as the vehicle's cameras and the resulting video is mixed and displayed with the vehicle's cameras. This form of generation of video is unique in that it is simple to obtain the proper perspective and can be easily changed if required due to a change in the vehicle's camera depression. The device, however, is based on a "crab" type steering (all the wheels turn) and does not provide the second form of information, the projected width of the vehicle on the terrain.

With some modification, this principle can be adapted to the Ackermann type steering and will show the additional information. In Figure 2-3, a unit

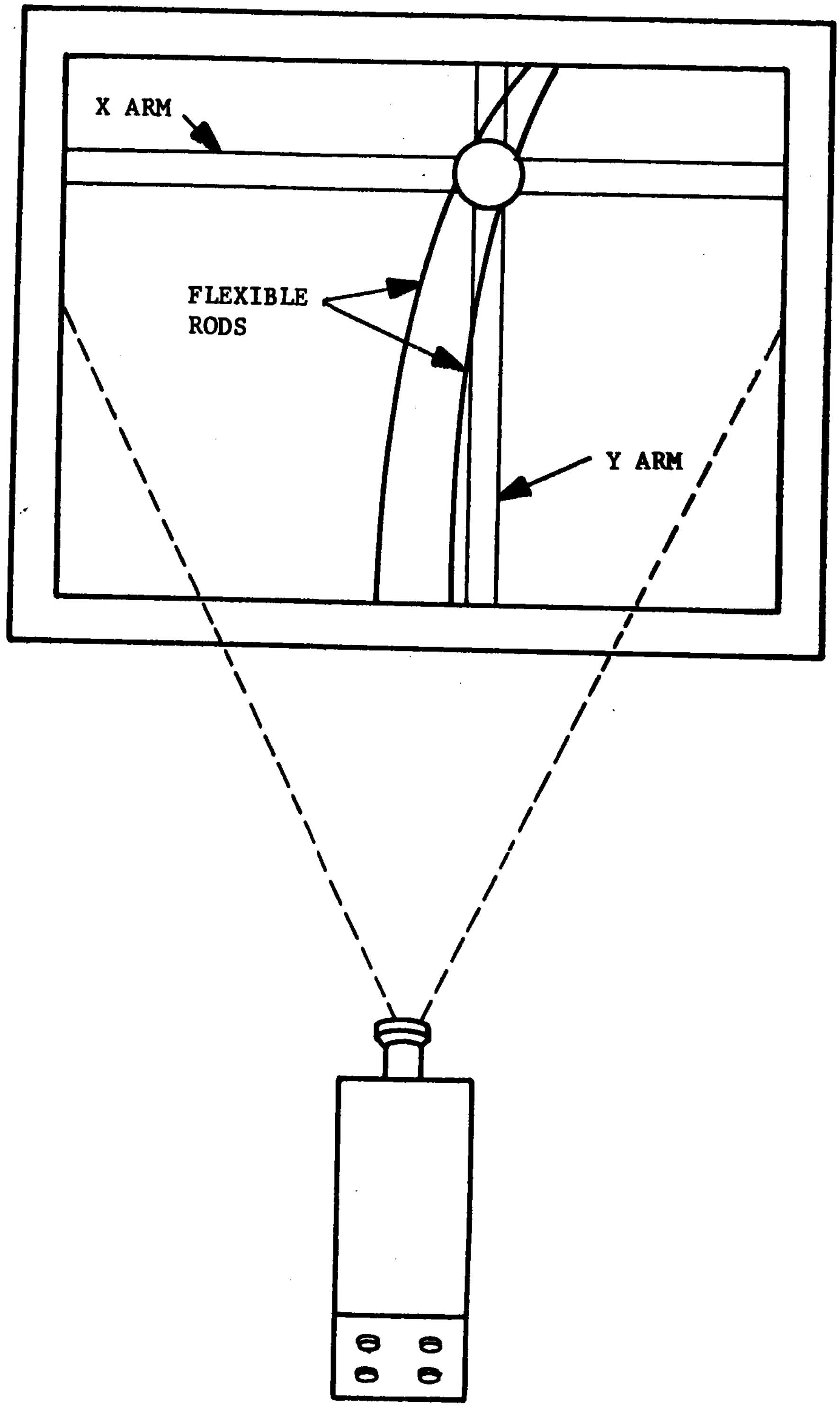


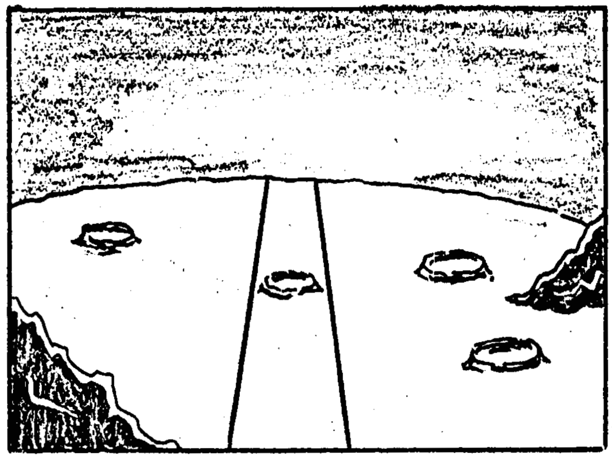
FIGURE 2-3 PREDICTOR VIDEO GENERATOR

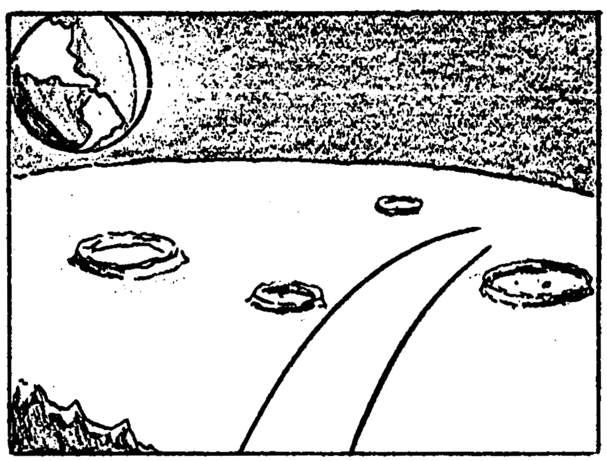
similar to an X-Y recorder is used with the exception that more powerful motors would be required. At the intersection of the drive arms, a metal block, free to turn, provides a sliding support for two flexible rods, anchored at one side of the recorder as shown. The television camera views the device from a position to the side and somewhat above the recorder as was used in the Stanford device. This again provides the proper perspective, to match the view of other video.

The two rods are the only parts reflective to light and therefore are the only parts that will be seen in the resultant video. The two rods will represent the tracks of the vehicle and therefore impart the width of the vehicle at any point on the approaching terrain.

The sketches of Figure 2-4 A and B show the effect of superimposing the flexible rods on the lunar terrain. The top sketch shows the future path with no turn inserted, while the bottom sketch shows the driver when he has inserted the proper amount of turn. The distance between the two lines, at any point, is indicative of the width of the vehicle on the terrain ahead. The lines indicate that the vehicle could safely go between the two craters but could not pass to the left of the center crater. The curvature of the lines shows the driver immediately when the correct amount of turn angle has been inserted. The ends of the lines can be used to show some future distance point which may be a specified distance or which may be computed as a function of the vehicle velocity and time. The portions of the rods beyond the pivot block can be eliminated from the video by placing a blackened light shield that is movable and is attached to the X-arm of the generator.

A





B

FIGURE 2-4 TERRAIN AND PREDICTOR SUPERPOSITION

It should be noted that the use of the predictor does not further complicate the vehicle, but does involve the ground equipment, with the only real system penalty (other than cost) being that the television display is somewhat cluttered by the superimposed display of the predictor output. The design of the display, therefore, is to include as much information with the minimum amount of clutter.

It was stated that the driver should only be concerned with obstacle avoidance and that overall course information could be fed to the driver by another operator. The information can be obtained from a plotter driven by the telemetered heading and velocity data. The plotter is initially positioned to the coordinates of the MOLAB point of landing and moves in coordination with the actual vehicle movement toward the desired final position, the point of landing of the astronauts. The second operator gives voice directions to the driver as he attempts to maintain a straight line path between the two points.

A final suggestion for the driver's station is to include the capability of recall, i.e., the driver should be able to look, on demand, at the previously recorded pictures. This could be done by pressing a button causing the monitor to display the previous pictures in a reverse order until a second button is pressed, resetting the recorder. Alternately, a dial is set to a given time, causing the recorder to rewind back to the specified point and then read out to the monitor the recorded tape. The procedure would only be done while the MOLAB is stopped and would be used for retracing a path while looking for an alternate.

2.5 DRIVING PANEL

In Figure 2-5, the complete driving panel is shown with the exception of the minor function switches for camera power, target and focussing adjustments, etc. The area marked "warning lights" is to indicate excessive temperature and other abnormal conditions. Included in this category are lights to indicate when the camera azimuth, elevation, and focal length are set to values other than those that the driver normally uses. This can warn him that the predictor indicator is not showing the correct values. A steering wheel is chosen rather than a "joy" stick since the problem is that of steering a ground vehicle and not an aircraft.

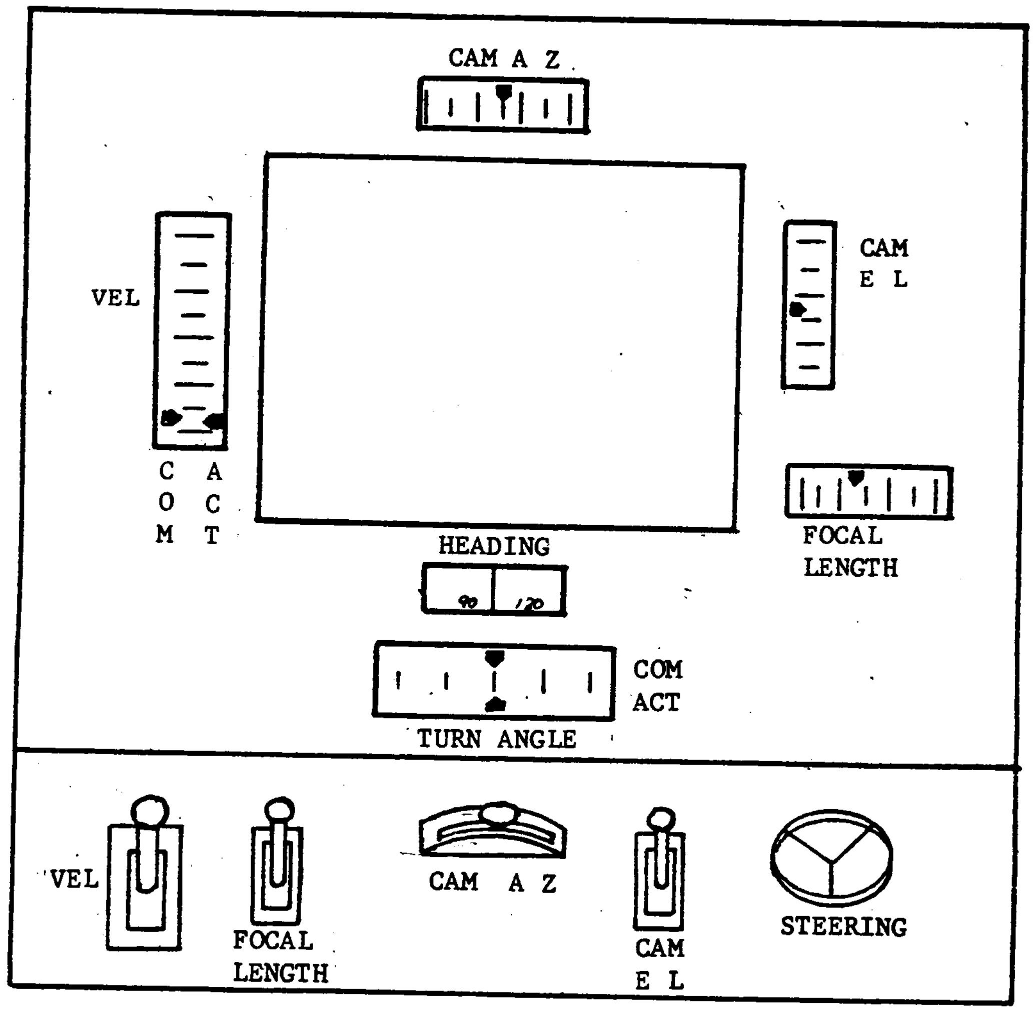


FIGURE 2-5 DRIVING PANEL

3.0 TELEVISION FUNCTIONS DURING THE MANNED PHASE

3.1 INTRODUCTION

During the manned phase of the mission, the stereo cameras no longer are prime in importance, as the astronauts perform the driving function. It is necessary, then, to consider any means in which the television system could be used to aid in the performance of the scientific mission. It is assumed at this time that the allotted bandwidth for television transmission is still available during the manned phase of the mission; however, if necessary, changes may be made to the television system in order to allot additional bandwidth for the telemetry of measurements made by the scientific package.

3.2 IMAGE SMEAR

It should be remembered that the television system is designed for a specific unmanned maximum velocity while the expected manned speed will probably be much higher (by a factor of 4 or 5). This higher speed can be expected to cause a smear problem, unless the camera shutter speed is lessened or a higher degree of stabilization is used. For example, the shutter speed is selected to prevent smear during the maximum rate of turn at the maximum unmanned speed of 1.5 meters /second. Operation at the highest manned speed of approximately 5 meters /second would result in some degree of smear during turns. For the astronauts to change the shutter speed when they arrive may cause some problem, depending upon the type of camera mounting. If the shutter is in the form of a rotating disk, a change in the driving speed of the motor could change the shutter speed but also would require a change in the frame rate of the system. A change in the shutter itself is feasible only if the cameras were internally mounted.

3.3 AREAS OF INTEREST

There are three possible areas of interest in the use of the television system during this unmanned phase. These areas are:

1. Observation of the lunar terrain, providing stereo pictures.

2. Observation of the astronauts when they leave the shelter of the MOLAB.

3. Observation of any instrument implaced exterior to the vehicle.

The order of the listing does not necessarily indicate a decreasing importance.

It can be assumed that a main function of the scientific mission is to provide extensive analytical photography of the lunar surface. One plan[24] provides a three camera synoptic view, with each camera exposed through a filter passing a different portion of the spectrum. The resultant film provides the high resolution and spectral analysis not available through the television system, but the return of the film depends on the total success of the entire mission, i.e., the safe return of the astronauts in the command module.

As backup to this phase of the mission, in the case of failure during the return trip, the cameras are provided with automatic developer and a sampling of the developed film is televised by a flying spot scanner and sent to the earth control station. The overall resolution of these pictures is now limited to the resolution capabilities of the flying spot scanner system which would be lower than that of the driving cameras. The developing flying spot scanning system then seems to be a duplication of effort of the already existing television system, and it appears that the overall performance of the mission could be improved by giving the television system a limited spectral analysis capability by the inclusion of selectable filters placed in the optical path. The limitation of spectral range occurs in the photocathode itself; however, sensors can be expected to have a visible and appreciable ultra-violet sensitivity for the same photocathode material. Tubes have been built with an infrared sensitivity but introduce additional cooling problems. The ground station observers would have the prerogative of making the choice of filters. In addition, the feasibility of increasing the resolution of the television should be considered where a reduction of frame rate could be used to achieve a greater number of lines of resolution as long as the limiting resolution is not exceeded. An increase in sensitivity would also accompany the change. In a comparison of the two ideas, the following characteristics are noted:

1. The integration processing system would probably not produce the quality that could be achieved if the developing were done in an earth laboratory. A greater choice of types of film also would result if the requirement of the incorporated developer were removed.

2. The time lag involved in the developing scanning process does not occur in the television system. The scientist on the ground has

almost immediate access to pictures (stereoptic) and can request additional photography of an area having a particular interest.

3. A slight savings in weight is achieved by the elimination of the developing processor and the flying spot scanner.

The observation of the astronauts by the television is of interest to the ground station, not only for the study of their movements while in the low pressure environment, but also in order to direct them to terrain features that only the trained selenographist may notice. Regarding the observation of the astronaut's actions, the one or one-half frame per second operation of the television system may be too slow for correct interpretation of the mobility problems and the requirement for a faster frame rate with a corresponding reduction in resolution may be more feasible. Since the actions of the astronaut would be expected to be relatively slow and deliberate, the increase in the frame rate may not have be too great to capture the motion. Also, this point of interest may have been investigated in prior mission to the degree that the astronaut's mobility is of only secondary importance.

Observation of instruments by television shows little interest except possibly in the case of the bore hole operations. The instruments have been selected or designed to produce results in the form of electrical signals that can be telemetered directly, and are not for physical observation or direct human interpretation.

3.4 CONCLUSIONS

The additions and modifications to the television system to enhance its function during the manned phase of the mission then would be to include a selectable filter capability and to provide a variable frame rate (three discrete values) modification to the synchronizing generator. The inclusion of variable shutter speeds is a possible variance but is not considered necessary. A slight additional weight penalty occurs only with the variable filtering.

4.0 FEASIBILITY OF TV MONITORS FOR THE COMMAND AND LUNAR EXCURSION MODULES

4.1 INTRODUCTION

It is desirable to consider the feasibility of including television monitors for the MOLAB Command Module and the LEM in regard to the weight, volume, and power penalties involved. The purpose of the monitor would be to observe the pictures being generated by the MOLAB and/or earth originated data sent to the modules, or to monitor locally produced television. It is assumed that the monitor must have the capability of operating in the depressurized module.

4.2 WEIGHT, VOLUME, AND POWER TRENDS

In order to see the trends in weight, volume, and power as the screen size varies, seven commercial transistorized sets were investigated. (See Figure 1-5.) The actual values are given but are not of primary importance; only the trends are important, as the values are averages of several models using the same size screen. At the 15 cm screen diagonal, the ratio of mass to unit length diagonal is approximately 0.3, decreasing to 0.23 at the 22 cm diagonal value. The volumetric ratio is more constant as the screen sizes increase, but does increase at a rate greater than unity. The volume-to-diagonal ratio is about 300 at the 12 cm diagonal and increases to 575 at the 22 cm diagonal.

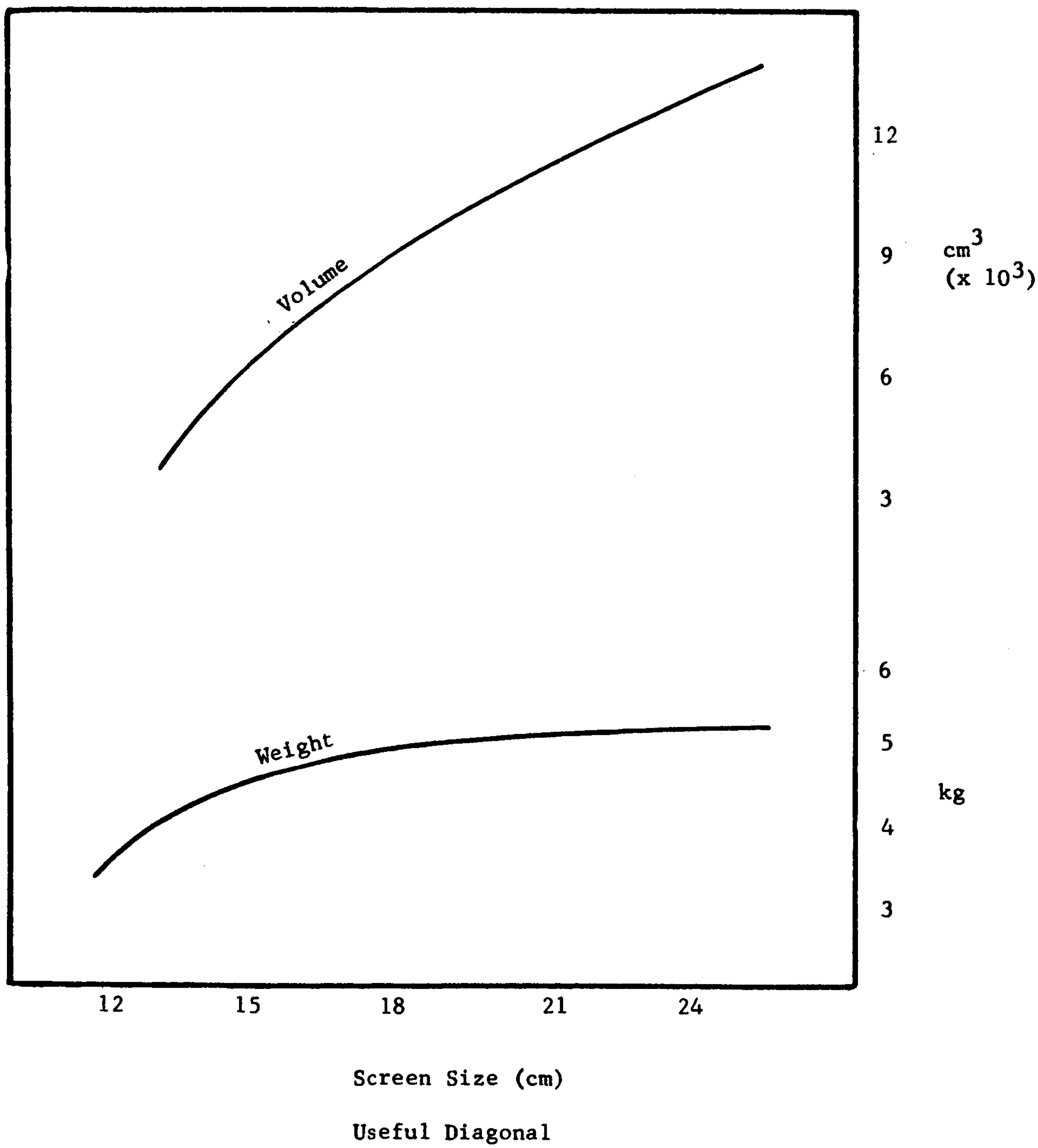


FIGURE 4-1 WEIGHT, VOLUME TRENDS FOR TV MONITORS

4.3 EXAMPLES OF MONITORS

As an example of a monitor designed for space environment including low pressure operation, the following data has been extracted.[25]

Screen Size	15 cm (6 in) useful diagonal
Volume	24585 cm^3 (1500 in^3)
Mass	9 kg (20 lbm)
Power Consumption	40 watts
Resolution	350 lines (min)
Light Output (Highlights)	30 foot-lamberts

The unit is ruggedized and is capable of operation at critical pressures of 0.1 to 0.3 psi.

The problems of low resolution occurring in these units could be overcome by the use of fiber faceplates. Resolutions can be increased by factors greater than 500 by this technique.

A second unit, also designed for space environment and using the 15 cm diagonal CRT, required 29500 cc and had the same mass. It required 60 watts power which was probably due to the extra scanning power required for operation at the high frame rate of 60 fields/second.

REFERENCES

1. Miller, L. D. and B. H. Vine, "Improved Developmental One-Inch Vidicon for Television Cameras", Journal of the SMPTE, Volume 67, p 154, March 1958.

2. Fink, Donald G., Television Engineering Handbook, McGraw-Hill Book Co., New York, 1957.

3. Neuhauser, R. G.,"Sensitivity and Motion Capturing Ability of Television Camera Tubes", Journal of the SMPTE, Volume 68, p 455, July 1959.

4. Neuhauser, R. G., "Picture Characteristics of Image-Orthicon and Vidicon Camera Tubes", Journal of the SMPTE, Volume 70, p 696, Sept. 1961.

5. Shelton, Charles T. and H. W. Stewart,"Pickup Tube Performance with Slow Scanning Rates", Journal of the SMPTE Volume 67, p441, July 1958.

6. Hurford, W. L. and R. J. Marian, "Monochrome Vidicon Film Camera", RCA Review, p 372, September 1954.

7. Murray, C. B., Jr. and A. Van Der Ziel, "Measurements of Noise in Image Orthicons" IEEE Transactions on Electron Devices, p 365, August 1964.

8. Glasford, Glen M., Fundamentals of Television Engineering, McGraw-Hill Book Co., New York, 1955.

REFERENCES
(Cont'd)

9. Kromer, Arthur S. "Photoemissive Camera Tubes", Electronics, April 24, 1959, p 92-93

10. Kromer, Arthur S., "Vidicon-Type Camera Tubes", Electronics, April 17, 1959, p 46-47

11. Neuhauser, R. G., "Vidicon for Film Pickup", Journal of the SMPTE, Volume 62, p 142, February 1954

12. Vine, B. H., R. B. James and F. S. Smith, "Performance of the Vidicon, A Small Developmental Television Camera Tube", RCA Review, Volume XIII, p 3, March 1952.

13. Neuhauser, R. G., "Camera Tubes for Color Television Broadcast Service", Journal of the SMPTE, Volume 65, page 636, December 1956.

14. Kohlmeyer, R. B., Some Evaluation of S/N Ratio and Bandwidth Restriction Effects on Television Picture Quality, Space Technology Laboratories, Inc., April 19, 1961.

15. Research and Development of a Family of Advanced Television Camera Tubes, Westinghouse Electric Corp proposal to Aeronautical Systems Division, USAF, May 1963.

REFERENCES
(Cont'd)

16. Lee, R. A., J. O. Hamby and E. L. Svensson, Advanced Television Cameras for Military and Space Systems, SDTM-275, Westinghouse Electric Corp., Air Arm Division, Baltimore, Maryland, Oct. 1, 1963

17. Bitting, R. C., et. al., Army Television Problems, Final Report Tasks - 3, 4, 5, for Coles Signal Laboratory, Fort Moumouth, N. J., RCA, July 24, 1956, AD 100843.

18. Adams, J. L., An Investigation of the Effects of the Time Lag Due to Long Transmission Distances Upon Remote Control, NASA TN D-1211, Stanford University, Stanford, California, December 1961.

19. Jordan, G. M., Remote Steering of a Lunar Surface Vehicle, Bendix Systems Division of the Bendix Corporation, Presented at the Michigan Navigation Conference Sponsored by Institute of Navigation, June 4, 1962.

20. Arnold, J. E. and Paul W. Braisted, Design and Evaluation of a Predictor for Remote Control Systems Operating with Signal Transmission Delays, NASA TN D-2229, Prepared under Grant No. NSG-111-61 by Stanford University, Stanford, California, December 1963.

21. Kinney, R. V., A Generalized Investigation of a Remotely Controlled Lunar Surface Vehicle, 1964 IEEE International Convention Record, pp 204-211, March 1964.

REFERENCES
(Cont'd)

22. Berbert, A. G. and C. R. Kelley, Piloting Nuclear Submarines with Controls that Look into the Future, Electronics, pp 35-39, June 8, 1962.

23. "'Moon Glow' Will Aid in Mapping", Bendix Systems Division, Ann Arbor, Michigan, Missiles and Rockets, March 1, 1965, p 25-26

24. ALSS Scientific Mission Support Study, Interim Report, BSR 1074, Bendix Systems Division, Ann Arbor, Michigan, December 1964.

25. Apollo Logistics Support System, Report D 2-36072-2, Boeing Company, Aero-Space Division, Seattle, Washington, January 1965.

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